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Queuing Approach to Estimate the MANET's Optimal Number of Nodes

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ABSTRACT

Mobile Ad-hoc Network (MANET) was defined as a set of mobile nodes that moved freely and connected among each other without any infrastructure or administrator control. Each node contains a kind of queuing system like buffer used it to serve the arriving packets that reached to the busy node. The packets reaches each node in certain sequence. The number of received (arriving packets) per unit time is called " arrival rate". The average rate or the average time between any two successive packets is called the inter- arrival time and follow certain statistical distributions. The node will serve the packets according to certain mechanism (discipline) like drop tail.

The effects of the service mechanism on the behavior of the MANET was studied and tested. Many queuing theory parameters were used to study and analyze the behavior of the MANETs. A mathematical model was built and implemented to estimate the optimal number of nodes required to be deployed in each new designed MANETs environment.

Key words*:* MANET, NS-2, DropTail, Mobility Model, Queuing, DSDV, Mathematical model.

INTRODUCTION

Mobile ad hoc networks (MANETs) are formed dynamically by an autonomous system of mobile nodes. These nodes are wirelessly connected without using an existing network infrastructure or centralized administration. MANET capabilities and its applications are expected to become an important part of overall next-generation wireless network functionalities. MANET's nodes are free to move randomly. Such network's topology may change rapidly and unpredictably. Each mobile node can have one or more network interface, each of which is attached to a channel . Channels are the conduits that carry packets between mobile nodes. When a mobile node transmit a packet to a channel, the channel distributes a copy of the packet to all the other network interface on the channel. These interface then use a radio propagation model to determine if they are actually able to receive the packet [D. B. Johnson, *et al.,* 1999].

Queuing theory is the process of handling the sequence of activities that arrives to certain server in certain shape. The server will serve these arriving units in certain order. In MANETs the nodes will serve the arriving packets in certain discipline (FIFO (Drop Tail), Priority, RED, ..etc). The effects of the sent packets mean inter arrival time and packets mean service times on the network nodes idle times , loss packets , mean servers (nodes) utilization and throughput were studied and analyzed in this study [M. Zukerman, 2012].

Queuing Concept

Queuing systems may be characterized by complex input process, service time distribution, number of servers, buffer size and queuing disciplines. Modeling simplification is often made when the aim is to analyze a complex systems. In communication networks the packets transmitted to their destinations will arrives at a router where they are stored and then forwarded according to addresses in their headers. Queuing network models can be classified into two groups: (1) open queuing networks, and (2) closed queuing networks. In closed queuing networks the same customers stay in the network all the time. No new customers join and no customer leaves the network. Customers that complete their service in one queuing system goes to another and then to another and so forth, and never leaves the network. In open queuing systems new customers from outside of the network can join any queue, and when they complete their service in the network obtaining service from an arbitrary number of queuing system they may leave the network [M. Zukerman, 2012].

Performance evaluation

Many performance metrics were developed to collect and report the required information to measure the performance of the networks. All of the measuring performance processes requires the use of statistical modeling to determine the results [Odge , 2003]. This study deals with the following important performance metrics.

Throughput

It is represents the mount of data received by the destination nodes through period of time [Ravi Kumar Bansal, 2006].

Throughput=receive packets/simulation time.

Dropped Packets

It is the number of packets that sent by the source node and fail to reach to the destination node [Aliff Umair Salleh *et al.,* 2006].

$$\text{Dropped packets} = \text{sent packets}_{(i)} - \text{received packets}_{(i)}$$

Mean inter arrival time

The arrival process is characterized by the arrival time ar_i of the packets or customers (received packets) and it can be computed by the following equation :

$$a_i = (ar_i - ar_{(i-1)})$$

Mean inter-arrival time is the summation of inter-arrival times by the number of received packets (n) :

Table 1: Simulation environment

Parameter	Value
The simulator	NS-2.34
MAC	802.11
Routing protocols	DSDV
Simulation time	90 second
Propagation model	Two ray ground
Transmission rate	4 packets/second
Mobility model	Random way point model
Queue discipline	Drop Tail (FIFO)
Traffic generation	CBR
Antenna	Omni Antenna
Packets size	512 bytes/packet

Table 2: The suggested MANET variables.

Case number	Nodes number	Speed	Pause time	Simulation area
1	3,4,5,6,7,8	10m/s	6s	500m*500m
2	4,5,6,7,8,9,10,11,12,13	10m/s	6s	800m*800m
3	6,7,8,9,10,11,12,13,14,15,16,17,18	10m/s	6s	1000*1000

Table 3: Results of average values with area of 500m*500 m

Metrics Number of nodes	Throughput	Packets loss	Arrival rate	Busy	Idle time	Utilization	Service time
3	4901	564.2	0.30644	61.2999	28.7002	0.68111	0.13202
4	6236	331.7	0.34349	50.626	39.3741	0.56251	0.14901
5	6247	329.8	0.36777	46.1836	43.8164	0.51315	0.16615
6	6142	353.9	0.37045	42.8364	47.1636	0.47596	0.18462
7	6114	351.6	0.42684	34.9166	55.0834	0.37896	0.17632
8	6274	330.4	0.55243	31.8342	59.9658	0.35384	0.183

Table 4(a): Results of average values with area of 800m*800 m

Metrics Number of nodes	Throughput	Packets loss	Arrival rate	Busy	Idle time	Utilization	Service time
4	3320.72	830.2	0.117110	71.0606	18.9394	0.789556	0.204100
5	3218.09	847.8	0.145617	68.6414	21.3586	0.762683	0.246475
6	2244.80	800.1	0.376222	68.5931	21.4069	0.762145	0.278026
7	3279.28	819.3	0.453144	57.0899	32.9101	0.634332	0.286874
8	3730.10	818.9	0.566250	55.2288	34.7712	0.613653	0.321705
9	3020.59	832.7	0.59967	51.6537	35.6463	0.573930	0.334493
10	3059.57	814.5	0.41770	44.4082	44.6918	0.493425	0.322479
11	3244.08	806.3	0.348626	40.4056	49.5944	0.448951	0.319153
12	2290.34	862.4	0.45243	38.7760	51.2230	0.430817	0.335777
13	3418.34	1902.3	0.381196	38.6807	51.2193	0.410342	0.366080

Table 4(b): Results of average values with area of 1000m*1000m

Metrics Number of nodes	Throughput	Packets loss	Arrival rate	Busy	Idle time	Utilization	Service time
6	1373	1101.8	0.305	74.75	15.25	0.831	0.322
7	2756	930.3	0.57	64.07	25.93	0.712	0.322
8	2631	1022.2	0.618	63.98	26.06	0.71	0.367
9	2856	1061.5	0.728	61.35	27.75	0.682	0.397
10	3217	797.8	0.752	50.26	39.44	0.562	0.363
11	2715	1059.4	0.836	50.49	39.51	0.561	0.398
12	2643	930.3	0.77	49.91	40.09	0.555	0.429
13	2781	919.4	0.669	48.19	41.9	0.535	0.451
14	2791	914.5	0.619	43.96	46.04	0.488	0.444
15	2723	892.7	0.549	41.49	48.51	0.461	0.449
16	2680	836.5	0.543	39.2	50.8	0.436	0.454
17	2358	977.4	0.478	39.39	50.61	0.438	0.481
18	2719	929.4	0.451	37.72	52.28	0.419	0.489

$$av = (\Sigma a_i / n)$$

System Busy time

system Busy time represents the total service times of the server [Hyungwook Park, 2009].

$$B = \Sigma s_i$$

System Idle time

If the queue is empty and the server is idle, a new packet is immediately sent to the node for service, otherwise the packet remains in the queue joining the waiting line until the queue is empty and the server becomes idle. The system idle time (I) can be computed by the following equation [Hyungwook Park, 2009] .

$$I = T - B \ .$$

Where T is the simulation time and B is the busy time.

Mean server utilization

the server utilization is one of the important indication to design systems that will maintain high utilization [M. Zukerman, 2012]. Mean server utilization is the percentage of time where the server is busy. The server utilization (U) can be estimated by the following equation.

$$U = B / T$$

Mean service time

Mean service time (S) is the average required time for each packet to be served (or to be forwarded for certain cases). It can be computed by the following equation :

$$S = \Sigma s_i / n$$

where s_i is the service time of i_{th} packets and n is the number of the sent packets.

Simulation Environment

The following suggested simulation environment was built and simulated in this study. Table(1) shows the proposed MANETs parameters and their types or values.

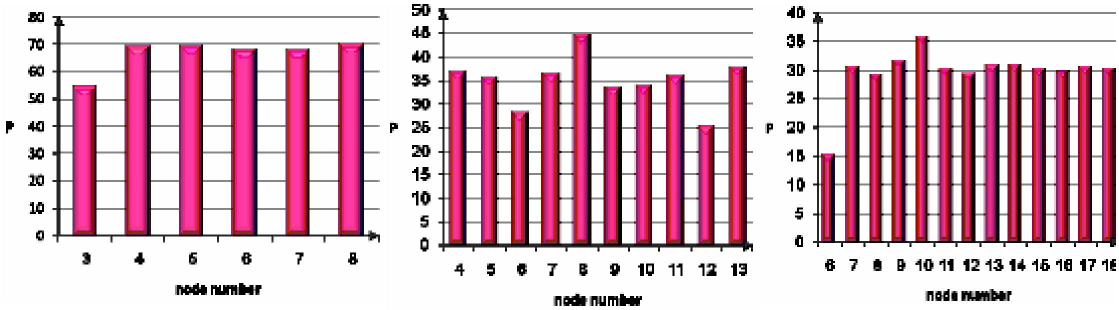
To evaluate the performance metrics with different MANET's parameters such as varying numbers of nodes and different areas. Table (2) shows these MANET's variables values.

Simulation results

In order to collect the required data and information to be used in queuing modeling, the following steps were proposed to be followed during the implementation of the NS-2 to simulate the suggested designed MANET scenarios in this paper.

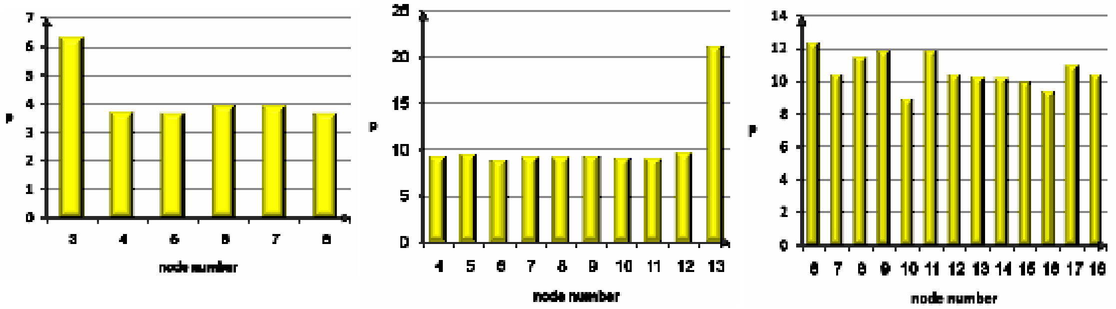
Tables 5: Results value and number of nodes with different area

Number of node	V
3	7735.174
4	10518.36
5	10893.28
6	10830.61
7	10813.63
8	10910.03
(a): Area of 500m*500m	
4	4496.434
5	4605.419
6	4781.228
7	6416.608
8	9207.82
9	6938.394
10	5647.1
11	5532.143
12	3975.586
13	3958.918
(b): Area of 800m*800m	
6	2033.63
7	6122.605
8	6145.126
9	7541.964
10	8977.607
11	7479.679
12	7383.792
13	7218.31
14	6126.22
15	6083.126
16	6039.263
17	5650.2
18	5516.251
(c): Area of1000m*1000m	



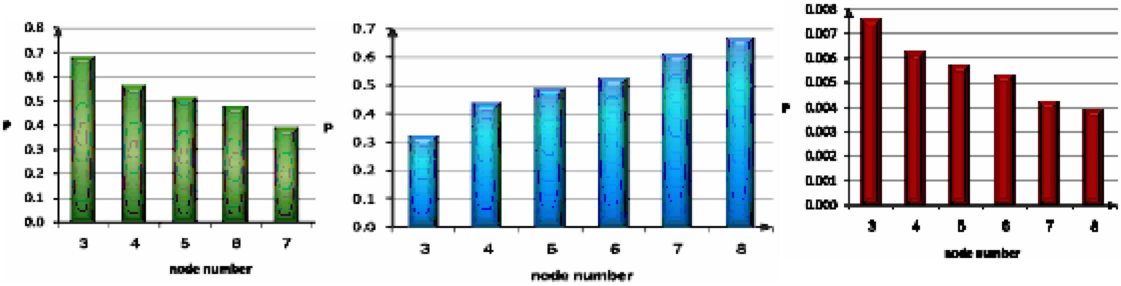
a . for area of (500*500) b . for area of (800*800) c . for area of (500*500)

Fig. 1: Throughput probabilities



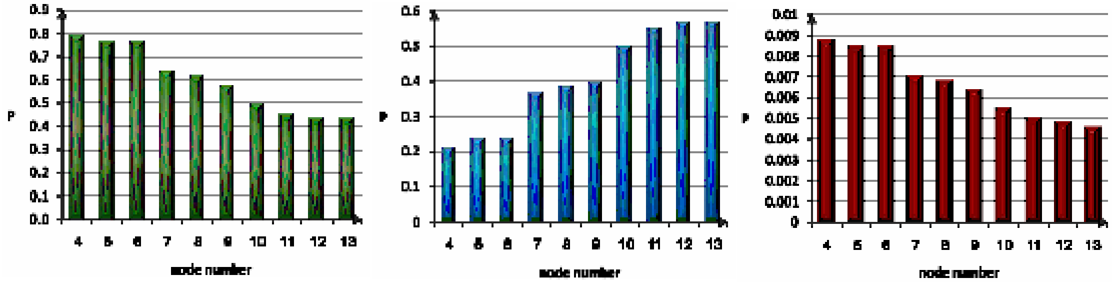
a . for area of (500*500) b . for area of (800*800) c . for area of (500*500)

Fig. 2: Probability of the lost packets



a . probability of busy time. b . probability of idle time. c . probability of mean server utilization

Fig. 3: The probability of busy ,idle and utilization with area of (500*500m)



a . probability of (busy time). b . probability of (idle time). c . probability of (mean server utilization)

Fig. 4: The probability of busy ,idle and utilization with area of (800*800m)

Step1: start.

Step2: build the traffic generators between the mobile nodes using the "cbrgen".

Step3: generate the movement file (scenario file) for the suggested MANET using the "setdest".

Step 4: build the "tcl" file that used to simulate the designed MANET's environment.

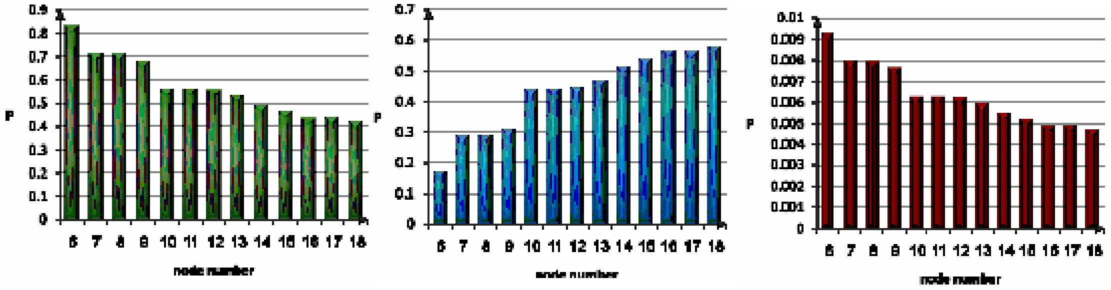
Step5: feed this "tcl" file with the traffic file and the scenario file to achieve the simulation process. At this step, two files (trace file and NAM file) are resulted.

Step6: compute the average values for each metric.

Step14: apply the mathematical model based on the average values for certain performance metrics (selected maximum value) which indicate the best number of nodes for this MANET.

Step15: End.

The computed performance metrics from



a . probability of (busy time). b . probability of (idle time). c . probability of (mean server utilization)

Fig. 5: The probability of busy ,idle and utilization with area of (1000*1000 m)

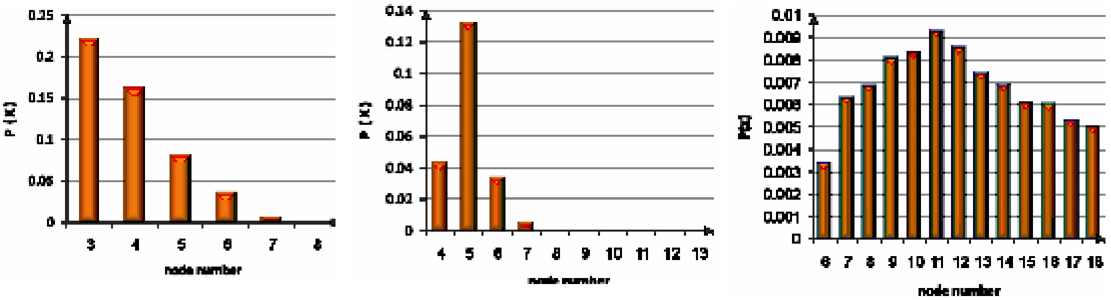
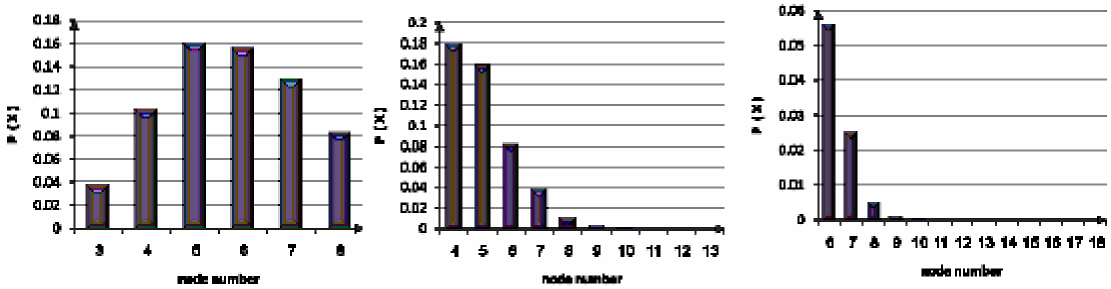


Fig. 6: Mean inter-arrival times for different number of nodes



a . probability with (500*500m) b. probability with (800*800m) c . probability with (1000*1000m)

Fig. 7: Probability of mean service time for varying number of nodes

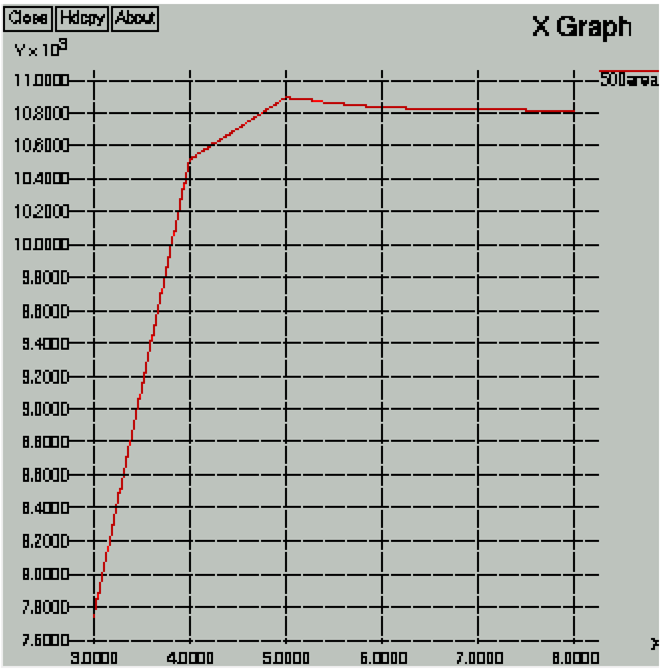


Fig. 8: Optimum value of nodes number for area of 500*500m

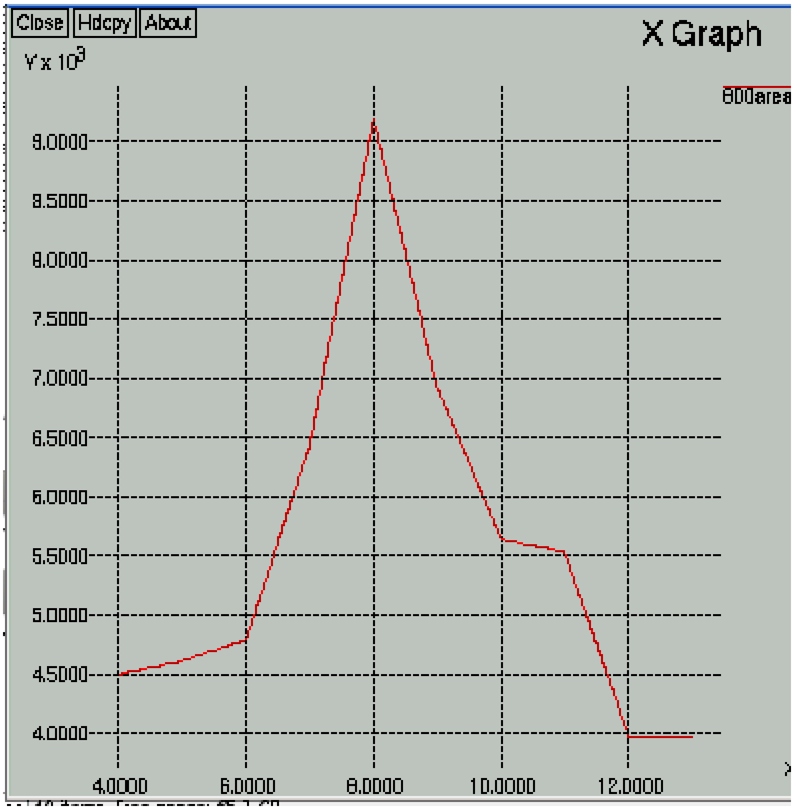


Fig. 9: Optimum number of nodes for the area of 800*800m

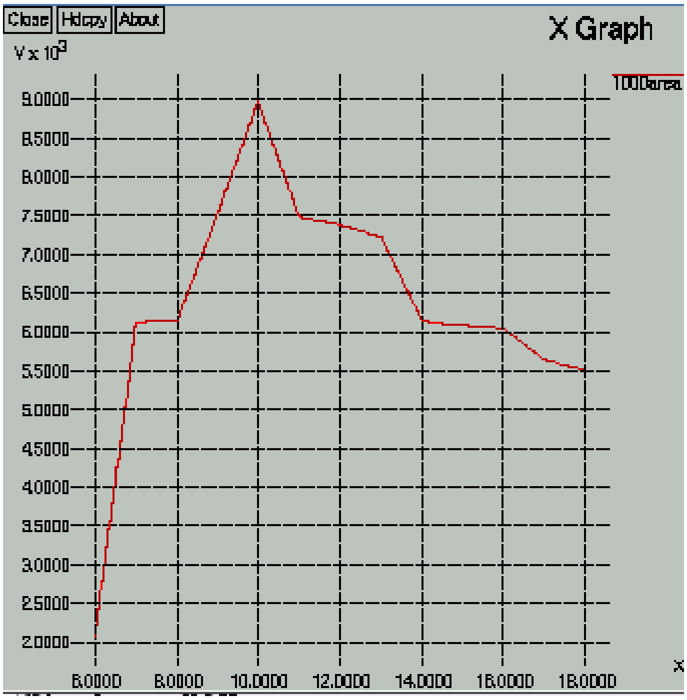


Fig. 10: Optimum number of nodes for the area of 1000*1000m

all the suggested MANET's scenarios with different areas and different number of mobile nodes were extracted. Each execution process produced trace file. The trace file is a general data file contains important information about the MANET's behavior. In this study certain important information's were extracted from the available trace file raw data. TCL and AWK programming were used as two programming tools in this extraction process. The queuing approach was used as the essential focus in this study. The main queuing parameters were considered to be extracted and estimated from these information and data. Each simulation process for each case was repeated (10 times to reach an average accurate value. The following tables shows the average values for each simulation area and different number of nodes.

Probability computations

The authors were tried to compute the probability of finding receiving packets of destination node during the simulation time with different areas using the following developed equation :

$P=\frac{av(i)}{Ts}$; av is the average execution of the10 runs and Ts is the run simulation time.

The similar equation was also used to compute the probability of the lost packets, busy time, idle time and mean server utilization during the simulation time. The following figures show these probabilities for certain performance metrics.

Figure (1) clarifies the probability of the throughput during simulation time within different with different areas.

Histograms in figure (3) show the probability of the busy time ,idle and utilization for varying number of nodes with area 500*500m.

Histograms in figures (4) and figure(5) shows the probability of busy ,idle and utilization for varying number of nodes with area of 800*800 m and area of 1000*1000m respectively.

$$p(x) = \frac{e^{-1/\lambda}(1/\lambda)^x}{x!}$$

Where λ is average of inter arrival time and x node numbers in above table.

Figure(6) clarifies the histograms of the arrival rate as probability distributions within all the different areas.

The Poisson equation was also used in calculating the service time as probability density function for each number of nodes with different areas :

$$P(x) = \frac{e^{-(1/\mu)} \times (1/\mu)^x}{x!}$$

Where μ is the mean service time and x is the number of nodes.

Mathematical model

Mathematical model is verified by experimentation and gives acceptable accuracy and provides a solution for selecting optimum number of nodes with certain area. So, this model gives more accurate information using the defined value probabilistic mathematical model. After experimentation with several equation on the calculated result tables.

The following equation was suggested and applied to calculate the value which indicate the best number of nodes in each area size.

$$V = (AV\_T_{(i)} + (AV\_U_{(i)} *1000) - AV\_L_{(i)} - AV\_I_{(i)})* e^{(\mu+\lambda)}$$

Where AV_T, AV_U, AV_L and AV_I are average of throughput, utilization, loss packets and idle time respectively. λ is the transmission rate(reception rate) and ì is the service rate.

This equation was applied and it is results were shown in tables (5) .These tables are clarifies the optimum number of nodes.

Figures (8) , (9) and (10) shows graphs to indicate the maximum value which indicate the optimum number of nodes for different areas. X graph tool that supported by NS-2 was used to draw the results in the following figures.

In figure (8) shows that for area 500*500m with DSDV protocol, the optimum number of nodes for this MANET is 5. This value represents the maximum value in the curve.

From this figure, the optimum number of nodes are 8 for the MANET area of 800*800 m if using the DSDV as a routing protocol.

Fig. (10) show that (10) nodes are optimal value for area 1000*1000 with routing protocol DSDV.

CONCLUSION

There are many tools that can be utilized to improve and develop the behavior of the MANETs. The well- known performance metrics were studied in the current and previous times by many researchers. This study concludes that there is a possibility to make use of many other performance metrics in addition to these well known metrics. These new metrics (or special used) were mixed with the other metrics to develop and estimate certain indications about the MANET's behavior.

A suggested mathematical model was built and implemented to compute the optimal number of nodes for each MANET's area with the use of the DSDV routing protocol. The optimum number of nodes are depending on the effects of the mean inter arrival time, mean service time, maximum throughput, mean service utilization, minimum idle time and lost packets. Ns-2 was used as a simulation tool in simulating each of developed scenarios. The AWK language was also used to estimate many performance metrics values.

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